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The ILLUMINATING ENGINEER

ELECTRICITY · ACETYLENE · OIL · GAS

Edited by LEON GASTER

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Illuminating Engineering Society.
(Founded in London 1909.)

Among other articles this number contains :—

Practical Limitations in the Projection of Light by J. A. Orange.

Gas and Electric Lighting of the Offices of the Consolidated Gas Co. by T. Schofield and C. L. Law.

The Spectral Analysis of Dyes and Pigments by M. Luckeish.

Scientific and Industrial Research (Report of Privy Council Committee).

THE COLOURATION OF ARC LAMP GLOBES—FLUORESCENCE AND PHOSPHORESCENCE—REVIEWS OF BOOKS, &c.

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EDITORIAL.

Industrial Reconstruction and the Technical Press.

A very useful discussion on the above subject took place before the Circle of Scientific, Technical, and Trade Journalists on September 11th, when Mr. E. J. P. Benn brought before the members a number of important proposals for the better organisation of the industries of the country. Mr. Benn has devoted a great deal of attention to these problems and has been associated with an influential movement in regard to British trade since the outbreak of war. His recent book on "The Trade of To-Morrow" excited keen interest, and it is recognised by thoughtful men that there must necessarily be vast changes in our methods of conducting trade and

industry if this country is to keep its proper place in the commercial fabric of the future.

The moment is not quite ripe for the discussion of this subject in great detail, but a considerable amount of preparatory work has been done by Mr. Benn and others and we understand that these problems will fall largely within the scope of the Ministry of Reconstruction. There can be no question that the ground for future advances must be prepared now. It is necessary to feel our way towards the new measures that will have to be taken after the war, and while, in the present dislocated state of industry, we can hardly expect immediate vast changes in capacity for production, we can at least institute enquiries, accumulate information, and prepare public opinion.

Attention has been constantly directed to the question of promoting better relations between capital and labour, and the Whitley Report, containing suggestions for the setting up of joint Industrial Councils strongly emphasised the necessity for better facilities for the discussion of labour difficulties and the prevention of industrial strife. The co-operation of employers and employees must be enlisted in the interest of their trade or industry. Their joint efforts must be devoted not only to the settlement of their individual differences, but to the application of scientific and industrial research, the promotion of welfare work and improved education, and the technical problems of manufacture, distribution, and publicity; in regard to the latter, especially, the trade and technical Press can play a most important part.

The Councils suggested under a scheme of Industrial Reconstructtion should therefore have a wide scope. Each industry should be mobilised for common action through its own representatives, and it is further proposed that above all there should be a separate Government Department for encouraging trade, assisted by an Advisory Council. Whatever the method of organisation adopted it is recognised that its main aim must be to remove the conflict of interests between various members of an industry and to enable them to unite their efforts for the common good. We find a general appreciation of the fact that in this country there has been too much individual effort and too little co-operative action.

The problem is a vast one, and there is one section of the community, the trade and technical journalists of the country, who could do a great deal to forward its solution. Editors of scientific, technical and trade journals are in close touch with the industries they represent. They often have access to information such as no individual manufacturer could present, and their journals constitute a medium for the communication of information and ideas to the industries of the country which could hardly be surpassed. There are two direct ways in which their services would be of immediate value, in the compilation of statistics and information, and in preparing the way for industrial reconstruction by discussing schemes and proposals in their columns. This preliminary ventilation of problems is essential. A vast scheme of this kind can only be made successful when the willing co-operation of the trades concerned has been obtained.

We feel confident that the scientific and technical Press will gladly co-operate with the authorities in paving the way for industrial advances, and in the Circle of Scientific, Technical, and Trade Journalists there is available the nucleus of a body through which this section of the Press could be conveniently approached.

Scientific and Industrial Research during 1916—1917.

In referring to the recently issued Report by Mr. A. P. M. Fleming on "Industrial Research in the United States of America" we expressed the hope that the Department of Scientific and Industrial Research would see their way to issuing supplementary publications descriptive of the work being done in this country.

The Report of the Committee of the Privy Council for Scientific and Industrial Research for the year 1916-17 is very timely in this respect, for it shows that its field of work is rapidly widening, and that manufacturers are becoming alive to the value of research and the advantages of co-operative work. A foreword to the Report by Lord Curzon briefly summarises the steps leading to the establishment of the Department, involving the devotion of a sum of £1,000,000 to be expended in research during the period of five years. This step was necessary to provide for continuity of work over this initial period. Reference is made to various channels through which this amount may be expended. The important announcement is made that negotiations have been concluded with the Royal Society for the transfer of the property of the National Physical Laboratory, together with the responsibility for its maintenance and development, to the Department. We sincerely hope that this change will have the effect of relieving the Laboratory from the embarrassments which have hitherto curtailed is useful work, and will enable it to fulfill more completely its objects of existence.

The Report of the Advisory Council is divided into two sections, Part I. describing general measures taken for the encouragement of research, and Part II. summarising the progress made in a number of specific investigations. A broad distinction is drawn between three varieties of research, those which can be profitably undertaken by a single individual or firm; those involving co-operation between a number of firms representing an industry, for the benefit of which, as a whole, the research is undertaken; and researches of such wide national value that they cannot properly be entrusted to a combination of manufacturing firms, but require State supervision on behalf of the nation. As examples of the latter form of research are mentioned the investigations of the Fuel Research Board, the British Fire Prevention Committee, and the Concrete Institute—and the scientific principles underlying illuminating engineering and cold storage are mentioned as other instances of problems which call for national action.

The field covered by various researches is extremely wide. Readers are referred to the abstract on pp. 209-210 for a more detailed account of these investigations. The formation of the Joint Committee on Illuminating Engineering which has already been announced in these columns, is duly recorded, while the references to work on Glass and Optics are specially interesting in view of the establishment of the Research Institute for Glass at Sheffield University, and the Institute of Technical Optics, with a proposed new department for research at the Imperial College. We are very glad to see that the Department have again followed the enterprising procedure adopted in connection with Mr. Fleming's treatise on Industrial Research in the United States, *i.e.*, by issuing with the Report an official abstract summarising its chief conclusions and some of the most important developments in research work during the last year. We feel sure that this practice, which we hope will become general among Government Departments, will be of great assistance to the technical Press in dealing with literature of this kind.

Illuminating Engineering and the Conjoint Board of Scientific Societies.

A Report issued by the Conjoint Board of Scientific Societies, noticed in our last number, referred to the steps being taken to develop National Instruction in Technical Optics. An Advisory and Administrative Committee, under the ægis of the Imperial College of Science and Technology, has been appointed and Mr. F. J. Cheshire has been created Director of Studies in Technical Optics. The need for better facilities for instruction in this branch of knowledge has long been recognised by the most enterprising sections of the optical industry, and we notice that the matter has also been receiving attention in France.

Optics is a subject that touches a very wide circle of industries and professions. Apart from its direct interest to manufacturing opticians and photographic experts it enters into the construction of a great variety of scientific instruments, and comes within the field of the medical man, the radiographic expert, the chemist and physicist, and many others. To illuminating engineers it has a direct interest in two obvious directions, the manufacture of photometric appliances and illuminating glassware. It is, however, scarcely possible to consider fully any appliance for the direction and distribution of light without the principles of optics coming in. A specially good instance of such applications is the manufacture of searchlights and projectors of all kinds, and the consideration of their most efficient use for the many purposes such appliances fulfil.

We therefore hope that in the educational scheme now being evolved the study of illuminating engineering problems will receive due consideration. No doubt the correlation of work carried on at the Imperial College with that undertaken at such institutions as the Northampton Institute and the newly established department of technical optics at the Sheffield University will be studied, and in all these cases there should be provision for the treatment of problems involved in the measurement and distribution of light.

The relation of such studies to the manufacture and use of illuminating glassware is particularly important. This matter has been receiving the consideration of the Illuminating Engineering Society of late, and there is ample evidence of the need for more scientific investigation of such glassware and the provision of facilities for testing not only the mechanical and general chemical and physical properties of glass for this purpose but also its efficiency from an illuminating engineering standpoint.

Illuminating engineering is now generally recognised as a subject of national importance, and the need of research in this field has been illustrated by the appointment of the Committee on Illuminating Engineering under the Department of Scientific and Industrial Research. We hope that this subject will receive due consideration in the programme of the Conjoint Board. We feel sure that the Illuminating Engineering Society would gladly co-operate in any measures that are taken for the advancement of the study of illumination or the solution of problems involving the practical application of light.

LEON GASTER.

REPORT OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (1916–1917.)*

This is the Second Annual Report issued by the new Research Department, which, under all the disadvantages of the strain of war and the shortage of workers, is trying to provide a permanent basis for research in this country and to co-operate with similar attempts in the Dominions.

The Report indicates that there are three ways of organising industrial research. The simplest is the case where a single firm can work out a problem and itself fully exploit the results. In most cases, however, problems of industrial research will concern many firms—sometimes many industries; they will require the expenditure of large sums of money and the co-operation of many workers for long periods of time. But if successful the results will be of immense value.

Most individual firms cannot undertake this long and costly process. Yet why should the State pay the whole cost of winning new knowledge which will be valuable to business men? It is to be hoped that the way out of this dilemma will be found by the establishment of "trade research associations" to be constituted as needed for each industry or group of industries on which are to be represented when possible capital, management, science and labour, and which are to be aided out of the Million Grant to be administered by the Department for the express purpose of establishing such research associations. One association is just about to be constituted for the cotton industry, others are being brought into existence for the wool, flax, shale oil and photographic industries.

There are also many cases where the problem is so complex or else so immediately concerns the consumer rather than the producer that co-operation between manufacturing firms is not possible. This is obviously the case with fuel. Hence the establishment of the Fuel Research Board, which under the direction of a distinguished man of science, Sir George Beilby, will itself conduct research. So, too, with the problems of fire-resisting materials and the determination of standards and constants. Among other such examples are mentioned the scientific problems underlying illuminating engineering and cold storage. All this is direct work for the whole community acting through its special organ of research. It is interesting in this connection that the Royal Society has negotiated with the Department the handing over of the financial responsibility for the conduct of the National Physical Laboratory, where investigations of national importance are constantly going on.

The main lines of policy of the new Department are being slowly worked out. But it is also not neglecting immediately pressing problems. In glass, for instance, a great deal has been already done. Three completely new kinds of optical glass have been discovered by Professor Jackson. A research on light alloys (aluminium, zinc and copper) will be of the utmost importance for the future of aeronautics. A new hard porcelain from purely British materials has already been produced. Researches into the recovery of tin are expected to save the Cornish tin industry £30,000 a year. A large number of other researches are being aided or carried on by the Department. Among these are mentioned domestic heating, atmospheric pollution and conditions in deep and hot mines, and mine-rescue apparatus. A great deal of work is also being done on concrete. Experiments are being conducted on hardness tests of journals and pins, flow of steam through nozzles, heating of buried cables, insulating oil, and the heat-treatment of high speed steel.

In connection with glass and technical optics two important steps have been

* To be purchased through any bookseller, or directly from H.M. Stationery Office, Imperial House, Kingsway. Price 3d. (by post 4d.).

taken. A Research Institute for Glass has been established at the University of Sheffield. Progress has already been made with several systematic investigations, such as the influence of small amounts of chlorides and sulphates in producing opalescence. These experiments will not overlap other enquiries and co-ordination in this respect has been greatly aided by the formation of the Society of Glass Technology.

The other important step in this direction is the step taken towards the foundation of an Institute of Technical Optics. This scheme involves the strengthening of the existing department of technical optics at the Northampton Institute, and the organisation of a special research department at the Imperial College of Science. A single specially constituted Committee is to survey the work of both institutions, the first director being Mr. F. J. Cheshire, lately associated with the department of optical munitions and glassware at the Ministry of Munitions of War. Revised versions in English of several standard works on Optics have also been authorised, and these will be issued at cost price.

A survey is also being made of the whole field for research and additions are being made to the committees dealing with specific subjects. Among such may be mentioned the appointment of a Joint Committee of the Illuminating Engineering Society and the Standing Committees on Engineering and on Glass and Optical Instruments. This Committee has been asked to make a survey of the whole field of research in illuminating engineering.

The Universities will take their place in the new social tissue whose pattern is now being woven. At a considerable number researches, aided or initiated by the Department, are now going on. At the Universities, too, the future research workers receive their training; and thirty-six (who would otherwise have drifted into immediately remunerative work) were aided by grants from the Department during 1916-17.

The Department has also given considerable thought to the question of encouraging inventors, whose interests will be protected, and who will receive assistance while their inventions are in the developing stage.

The Report ends by noting the altered attitude of manufacturers and men of business towards the claims of research and education, and reiterates the conviction that a sure advance in industrial science can only be made when the field of work is adequately surveyed beforehand and an organised plan of attack carried out.

ILLUMINATING ENGINEERING SOCIETY (U.S.A.).

CORRESPONDENCE CONVENTION.

IT will be recalled that owing to the war the usual Convention of the Illuminating Engineering Society in the United States will not take place, but arrangements have been made to circulate the papers submitted with a view to discussion by correspondence.

We understand that the first items on the programme are as follows :—

Presidential Address : W. J. Serrill.

Report of Committee on Nomenclature and Standards : A. E. Kennelly (*Chairman*), C. H. Sharp (*Secretary*).

Illuminating Engineering Publicity : G. H. Stickney.

Economics of Large Building Lighting : C. L. Law and J. E. Buckley.

Illumination Intensities in Large New York Department Stores : W. F. Little and J. F. Dick.

THE ENGINEERING COUNCIL IN THE UNITED STATES.

An important step in the United States has been the formation of the Engineering Council, representative of the leading engineering bodies, to assist the Government in war work. The Council has appointed a War Inventions Committee, which will co-operate with the Naval Advisory Board and other departments at Washington in the solution of war problems. Another Committee has been formed to collect information regarding engineers in the country, and to assist the Council to co-operate with the Authorities by meeting the need for the services of engineers in connection with the war.

PRACTICAL LIMITATIONS IN THE PROJECTION OF LIGHT.*

By J. A. ORANGE, Research Laboratory, General Electric Company.

Preface.

The art of lighting is divided into two sections, ordinary lighting and optical lighting. Most problems connected with the lighting of rooms and streets fall in the one section while all such things as searchlights, magic lanterns and moving picture machines belong to the other. Projection is a convenient term which is used to denote the latter division.

The distinguishing feature of ordinary lighting problems is that the lamps used can fairly be treated as point-sources (except in the matter of glare). Projection questions, on the other hand, will not admit of this kind of treatment, at least if quantitative results are required.

Introduction.

The only sources of light which can be treated as point-sources are the stars.

It is true that the action of any source may be deduced by considering it as a group of infinitesimal elements and accounting for each one in turn. There is, however, another method which is far less involved.

Brightness.

We must first understand what is meant technically by brightness. The term is used of surfaces—not necessarily surfaces of imposing extent, for the finest wire is considered at times—and it is a matter of appearance as determined by the conditions of the moment. Thus white paper in a dark room has zero brightness, in average daylight the brightness would be of the order of $\frac{1}{6}$ of a unit, and in strong sunlight 15 units. Brightness may be due to self-luminosity, as in the case of red-hot iron or phosphorescent paint in a dark room, or it may arise indirectly as in the case of all ordinary objects in a lighted room.

Thus the illumination values at various points due to a red-hot poker follow the same rule as do those due to a painted model of the poker illuminated in an appropriate fashion. Similarly, the illuminating effect of a d-c. carbon arc might be reproduced by a model having a crater represented in white paint. In both cases the sole difference would be one of the scale of values and would be explained entirely by the differing degrees of brightness.

Brightness does not depend at all on the distance of the observer and it is often nearly independent of the angle of viewing.*

There is now the question of a suitable unit in terms of which brightness may be expressed. The most convenient system is this: consider the illuminating value of one square inch of a surface relative to points lying on a perpendicular drawn from the centre of that square inch.

Confining the attention for the moment to points which are a foot or more away from the surface it is found that the illumination varies with great exactness as the inverse square of the distance. A similar illumination might be obtained by placing a small lamp of suitable candle-power in place of the one square inch of surface. The candle-power of such a lamp is a measure of the brightness of the surface and we may say that the brightness is so many candle-power per square inch. It follows that the illumination at any point in such a case will be the same whether we have one square inch of surface at 3 feet, or 4 square inches at 6 feet, or 100 square inches at 30 feet. The appearance of the surface as viewed from the point is exactly the same in all of the cases, or, stated more strictly, the solid angle subtended is the same. If the view of a surface is limited entirely by an intervening frame or window, the solid angle subtended by the window and the degree of brightness of the surface together determine the illumination received. How

* From the *General Electric Review* (U.S.A.), slightly abbreviated.

* A surface which exhibits this latter effect perfectly is said to obey Lambert's Law.

far the surface is behind the window or what its inclination may be is of no consequence.

Considered in this way, illumination effects are very easy to understand. A few examples will be inserted here to familiarise the reader with these methods.

No. 1. Suppose we have a perfectly even, clouded sky which has a brightness of 2 candle-power per square inch. A room with black walls is lighted solely by means of a hole in the roof, 10 square inches in area. The illumination at a point 6 feet directly below the hole will be $\frac{10\times 2}{6^2}$ ft.-candles $= 0{\cdot}55$ ft.-candles. If the hole were 30 square inches in area then the illumination would of course be $\frac{30\times 2}{6^2}$ ft.-candles $= 1{\cdot}65$ ft.-candles. However, at 10·4 feet below such a hole the illumination would be $\frac{30\times 2}{(10{\cdot}4)^2} = 0{\cdot}55$ ft.-candle, the solid angle being exactly the same as that subtended by a 10-square-inch hole at 6 feet.

Next, consider a point which is not directly under the opening but off in a slanting direction—say 60 deg. with the vertical. The appearance of the hole from such a point will be very different. In fact a hole of 10 square inches will have an *apparent* area of 5 square inches. The illumination at such a point, then, if the distance from the hole is 6 feet, will be $\frac{5\times 2}{6^2} = 0{\cdot}28$ ft.-candle. If instead of using the sky we have a large white sheet stretched, say 10 feet above the hole, the illumination conditions in the room will be unchanged, provided the brightness of the underside of the sheet is the same as that of the sky.

The idea to be grasped is this. We can determine the illumination produced at any point by a bright object if we know exactly what is the appearance of that object as viewed by an eye placed at the point in question. The "appearance" includes two factors, brightness and *apparent* size; the latter is identical with the "solid angle" subtended.

No. 2. Metallic tungsten, like all other substances, becomes self-luminous when hotter than about 500 deg. C., and gains rapidly in brightness as the temperature is raised. At a temperature of 2,000 deg. C., its brightness is some 740 candle-power per square inch. Suppose a lamp has a filament of tungsten operating at this temperature, which is to say, at this brightness. The illumination produced at any point can be deduced immediately if we know the apparent area which the filament presents towards that point and also the distance of separation. These two quantities together measure the solid angle subtended by the filament surface, but the solid angle is, after all, derivable directly from the appearance of "view" of the surface from the point in question.

The commonest type of tungsten lamp, viewed from the side, shows twelve straight pieces of wire in "full-face" view. Taking the lengths as 2 inches and the breadths as 0·002 inch, we have $12\times 2\times 0{\cdot}002$ square inches approximately as the total area presented to view. The candle-power of the lamp with respect to points opposite the side is therefore $12\times 2\times 0{\cdot}002\times 740$ (at 2,000 deg. C.). The further we go away from the side of the lamp, that is by moving around so as to face the tip, the smaller the apparent area of the tungsten becomes. It is halved by the time we reach 60 deg. away from the side, roughly speaking. The candle-power in that direction is correspondingly smaller. More exact information as to the value for any point could be obtained from a photograph of the lamp taken with the camera lens at that point.

No. 3. The d-c. carbon arc is effective by virtue of a very bright circular patch on the end of the positive electrode. This patch (or crater) is of even brightness and the "distribution curves" for such a lamp are determined solely by the apparent (or foreshortened) area of the crater as seen from different points. The peculiar form of those curves is entirely due to the limited view of the crater as seen from certain standpoints, the obstruction being obviously caused by one or other of the electrodes.

The following Table gives the rough values of surface brightness assigned to familiar surfaces.

Two things should be noticed, the enormous range of values as between different illuminants and the approximate constancy for any particular one irrespective of size of source and consumption.

Table of Brightness Values in Candle-Power per Square Inch.

White paper in bright sunlight ..	15
Coal gas flame	3
Kerosene flame	0·9
Acetylene flame..	30–60
Welsbach mantle (mean)	30
Carbon filament	750
Tungsten filament (ordinary vacuum practice)	1,000
Tungsten filament (ordinary gas-filled practice)	2,000–7,000
Nernst lamp glower (max.)	3,000
Limelight	2,000
Tungsten filament (special practice)	24,000
D-c. carbon arc crater, from 3 amps. upward	84,000
The sun at mid-day	600,000

Mirrors.

We are now in a position to appreciate a very useful generalization relating to optical devices. The appearance of any mirror, viewed from any point whatever, must always be what might be called a mosaic of surfaces exhibiting some or all of the brightness values of the surrounding objects.* It will be be granted immediately that this holds in the case of plane mirrors, the "looking glasses" of every-day use. That it holds equally for all curved mirrors may be readily ascertained if a little attention be given to the polished silverware of the table.

The Searchlight.

The searchlight is a familiar example. It is an instrument for producing illumination at great distances and it consists essentially of but two parts, a mirror and a light-source. The latter, as previously explained, is merely a bright *surface* of some size or other.

Suppose we consider the apparatus in use and station ourselves at the point to be illuminated. How may the illumination obtainable at that point be estimated? Why, the case is a simple parallel to those considered already and we shall observe the mirror to be sharply divided into areas *having the brightness values of the surrounding objects.* Here, however, there is the greatest disparity between those values: the carbon arc crater, assuming that to be used, will have a brightness of 84,000 candle-power per square inch while no other object adjacent is likely to have a brightness of more than 1/10 candle-power per inch square. The observer will notice only that area of the mirror which is as bright as the arc crater, all the rest will seem absolutely dark in comparison. The illumination obtained follows immediately, thus if the bright part of the mirror is apparently 20 square feet or 2,880 square inches and the distance is 5,000 feet the illumination must be $\frac{2880 \times 84{,}000}{5000^2} = 9{\cdot}6$ foot-candles. We can also decide at once that if the *whole* apparent area of the mirror is 25 square feet=3,600 square inches, the maximum illumination possible with that mirror at 5 000 feet (when any ordinary carbon arc is used) is $\frac{3600 \times 84{,}000}{5000^2} = 12$ foot-candles. There is thus an evident limitation as regards the illumination attainable at any particular distance and there are two factors in this limitation, the apparent area of the mirror presented and the brightness of the source-surface.

Mirror size is limited by cost and unwieldiness, while source brightness is limited to the values characteristic of the types of illuminant available.

In all of this we have given no attention to the form (curve) of the mirror and the dimensions of the source-surface because these matters are not involved in the considerations given. Nevertheless, the form of the mirror is important because it determines how large an extent of source-surface will be needed in order that the mirror appearance from the point considered shall *all* be bright and hence maximum illumination be obtained. The extent of the source, beyond the degree involved in this last condition, is only significant as determining the lateral range of points enjoying such illumination, in other words the "size of the spot thrown."

It will be readily understood that the only difference between an ideal mirror surface reflecting 100 per cent. and a practical one reflecting say 90 per cent. is that the brightness values observed in the latter are reduced to 0·9 of their original values and consequently the illumination is 0 9 of its ideal value.

The special suitability of the parabolic mirror and the connection between source size and area of the illuminated "spot"

* For the moment, mirrors will be assumed to have 100 per cent. reflectivity. The actual value for silver is 93 per cent. and the difference may well be neglected temporarily.

are entirely matters of geometry which would be out of place here.

Lenses and the like.

The generalization which has been established for mirrors in the foregoing has its exact counterpart in connection with all transparent bodies having polished surfaces, that is excluding all diffusing (roughened, etched or frosted) surfaces. Most table glassware complies with this condition; on looking *through* any part of a water-bottle for example, we see within the outline of the bottle as a frame a mosaic of surfaces showing some or all of the brightness values of the surrounding objects—and no others.*

Once more we can argue that results which hold for the diverse, complicated and arbitrary shapes of tableware may be expected to hold for the simple forms used as *lenses* by the optician.

The Post-card Projector.

As an application of this result we may take the common post-card projector. The usual arrangement comprises a holder for the card, means of illuminating the card—that is to say of rendering the card bright—and a system of polished glass pieces known collectively as an objective.

We are not now concerned with the art involved in giving those glasses the precise curves which result in the post-card picture being reproduced faithfully on the screen or curtain.

The illumination at various points on the screen is what we are interested in and it is very easy to determine what the values will be. If we go close to the screen and look back at the objective, placing the eye well within a sky part of the picture, the whole opening of the objective will show a brightness identical with that of the white part of the card.† Why this should be is not perhaps self-evident but a little argument will make it clear.

That very property of the objective which leads to the faithful reproduction of the picture necessitates that a screen point, which is for example part of the pictured sky, shall derive light only from the corresponding part of the card. If the eye, looking back at the objective from that point could see any part of the objective endowed with the brightness of some separate part of the card (other than that under consideration) this condition would be violated.

Once more, then, we have a relation giving the illumination at any point on the screen. Suppose that from that point the apparent area of the objective opening is six square inches, the brightness of the opening (or the brightness of the corresponding part of the card) is 50 candle-power per sq. in. and the distance of the screen point from the objective is 8 feet, then the illumination is obviously $\frac{6 \times 50}{8^2}$ foot-candles.

For any particular screen distance the illumination (and hence the brightness of the picture viewed) is determined by the brightness of the card and the effective area of the objective opening. In practice a limit to the brightness of the card is set by the heating effect accompanying the powerful illumination which must be used.

The practical size of the objective is the other limiting factor.

The Magic Lantern.

The magic lantern is related to the post-card projector but is an instrument with much greater possibilities. The difference is due primarily to the different kinds of pictures used; the post-card has the property of scattering light in all directions and consequently merely a fraction of this can reach the objective; expressed in other words, the brightness of any part of the card is very low relative to the intensity of illumination used.

The slide used in magic lanterns is entirely different. It may scatter a little light but there is so much which is not scattered that a vastly better economy is possible as compared with the post-card.

An objective is used, just as in the case of the post-card projector.

There is a combination of lenses somewhat larger than the slide, just behind it. This is followed at an appropriate distance by a very bright source surface. Following the preceding line of argument and considering the appearance of the

* Losses due to reflection and absorption are here neglected.

† We are neglecting certain losses which occur in all lenses: viz., by reflection and by absorption. This applies also to the magic lantern and moving-picture machine but in none of these cases is the effect very large. Furthermore, the corresponding factors are easily introduced by anyone who is interested in the matter.

objective as viewed from the screen we find that some or all of the objective opening is as bright as the source while the rest has the negligible brightness of the other contents of the lamp housing. The view from different points on the screen will show that the bright area of the objective is not the same for all, sometimes it lies in the centre of the opening and sometimes it lies more or less to one side. But the *size* of the bright part is substantially constant for all viewpoints.

It is not necessary to repeat the expression for the illumination. The limitations are clearly the brightness of the source and the area of the objective opening *serving any one point*. The question of how much objective area can be provided for this service is an optical one similar to that of providing "working aperture" in a camera or a post-card projector.

It is interesting to note, however, that in the early days kerosene flames were used (9 c.p. per sq. in.). The brightness of this source is so low that large working aperture is essential in the objective to obtain reasonable illumination. Modern illuminants like the special tungsten lamps and the carbon arc have such a vastly greater brightness that the aperture requirement is not hard to meet unless the screen distance (and with it usually the size of the screen-picture) is inordinately great.

The Motion-Picture Machine.

The motion-picture machine is a comparatively complicated piece of apparatus although it is closely related, optically, to the magic lantern. The lantern slide, which is about 3 inches long, is replaced by a similar picture, on celluloid, about 1 inch in length. In present practice the picture is held in place for a small fraction of a second, an opaque shutter then intervenes and cuts out the screen illumination entirely while the picture is being replaced by another, the shutter moves away and the projection of the second picture proceeds for a fraction of a second.* The apparent illumination on the screen is an average of the effects of this regular succession of exposures. The best result which is practicable is an average illumination of about 60 per cent. of that attainable if these alternations did not occur.

* Actual practice is more complicated, in order to prevent flicker.

Comparing the motion-picture machine with the magic lantern, the same kind of limitations are found to govern the illumination on the screen.

Again we have the working opening of the objective and the brightness of the source. However, if the screen distance and the size of the screen picture are the same in the two cases, the objectives required will be very different. Just as in the case of cameras, where a large plate means a long camera with a big lens and a small plate a short camera with a small lens (if the conditions are at all similar) so in the present case the large lantern slide can be provided with an objective proportionately larger than can be provided for the motion-picture film—equal quality of design being assumed.

As a consequence, the objective opening used in motion-picture work would be small as compared with that found in magic lanterns, and hence the screen illumination would be small, were it not for the fact that the lens makers have pushed the objective design further for the motion-picture outfit and thus reduced the disparity. To some extent this has involved a rather inferior sharpness in the projected picture but to detect this requires a critical examination which motion-pictures do not receive, for obvious reasons.

The typical outfit of to-day, using the carbon arc as the source, is arranged in such a way that no part of the screen gets the benefit of the whole actual opening of the objective. It is possible by using different arrangements to secure that every part of the screen is served by the whole objective opening. The gain in working aperture is sufficient to offset the difference in brightness which exists between the arc crater and specially designed tungsten lamps. This means that in the great majority of cases it is possible to attain the present illumination values if we replace the present arc arrangement by a suitably arranged tungsten lamp and leave the objective as it is.

The injury to the sharpness of the picture which follows the increase of working aperture involved in this change is not such as would be noticed by the lay observer; even if it were so, the present objectives do not represent the limit of design and their cost is a minor item in the outlay which motion-pictures demand.

WORKS LIGHTING.

We notice a series of useful contributions under the above titles by Mr. D. H. Ogley in *The Automobile Engineer* for June, July and August in the present year.

In the first article the general principles of good industrial lighting, as summarised in the Report of the Home Office on Lighting in Factories and Workshops, are explained; data and diagrams being included to illustrate the prevalence of industrial accidents during the dark winter months, and their relation with inadequate lighting. Reference is also made to the necessity of periodical cleaning and maintenance. Curves are presented showing the progressive diminution in illumination during 40 weeks due to deposits of dust on uncleaned lighting appliances which may amount to 15—35 per cent., according to the nature of the reflector. According to these tests the enamelled iron units come out best in this respect. By an actual example of a half-watt installation it is shown that the cost of periodical lighting is small in comparison with the money-value of the saving in light. The former is reckoned to be only 8s. for a period of 24 weeks while the saving in illumination is equivalent to £4 9s. These considerations also apply to depreciation in natural lighting through windows.

Reference is also made to such matters as avoidance of glare, uniformity of illumination, and colour value.

The next article deals with gas lighting, various typical lamps being shown, the manufacture of incandescent mantles described, and the possibilities of high-pressure gas lighting referred to.

The third article of the series, which is to be continued, deals mainly with the planning of installations. A number of illustrations of gas-lighted installations are shown, most of which will be familiar to readers of this journal. There is also a brief summary of the progress of electric lighting, and a comparison is made between half-watt and arc lighting. Mr. Ogley is a member of the Illuminating Engineering Society, and in this series of articles he refers to a considerable amount of information that has been contributed before the Society from time to time.

THE ELECTRIC LAMP INDUSTRY IN JAPAN.

Quoting the *Japan Chronicle*, the *Electrotechnische Zeitschrift* draws attention to recent progress on the part of the electric lamp manufacturing companies in Japan. Shortly after the outbreak of war, Russia is said to have invited orders for 20,000,000 lamps and Japan is filling many orders to that country which formerly would have gone to Germany.

A summary is given of the outputs of various Japanese companies, which, according to the information last available, can turn out more than thirty million lamps. This is sufficient to more than cover the home demand, and in view of probable subsequent extensions it is thought that Japan will be able to export lamps to a much higher figure in the future.

THE GAS INDUSTRY IN GERMANY.

An account of the difficulties experienced by gas works in Germany is given in the President's address to the German Gas Association, which is translated in the *Gas Journal*.

The shortage of coal has led to a demand for restriction of consumption, though it is suggested that this can hardly be expected in the industrial field, and that the only suitable outlet for economy lies in domestic lighting.

An interesting method of procedure is adopted at Crefeld, where 17s. per 1,000 cubic feet was charged for any gas consumed in either November, December or January which was in excess of the consumption during the month of November.

GAS AND ELECTRIC LIGHTING OF THE GENERAL OFFICES OF THE CONSOLIDATED GAS COMPANY.*

By T. Schofield and C. L. Law.

The account given in a recent paper before the Illuminating Engineering Society, U.S.A., by Mr. Schofield and Mr. Law, of the lighting of the above offices presents several interesting features. We have not only the interesting case of gas and electric lighting being employed to light in different sections of the same building. We have also a good instance of the application of both systems of lighting to very similar problems, and a general uniformity of treatment showing how, by the aid of modern lighting appliances, both systems of illumination can be made to yield substantially the same lighting conditions.

In both cases semi-indirect lighting is very largely employed, being used in the main offices, and only supplemented by direct lighting in the less important rooms. Moreover, the design of fixture used in both cases is the same, being merely converted to electric lamps in one case and gas mantles in the other. A further resemblance is secured by the use of distance ignition with the gas lamps, enabling them to be controlled from a distance.

So far as one can judge from the illustrations and the data for the illumination provided, the lighting conditions are substantially the same in both installations. The good features of semi-indirect lighting, avoidance of glare, good diffusion, and uniformity of distribution appear to have beed generally secured. Figures are also given for the brightness of the bowls (approx. 250-600 millilamberts in the case of gas and 500-1,000 in the case of electricity), and as these values are below the brightness of the average white sky, and the units are well up out of the range of view, the effect should be quite satisfactory from the standpoint of avoidance of glare. A comparison of the brightness of the bowl with that of the ceiling above shows that the ratio was invariably within 1 : 60, which appears moderate.

The photographs reproduced in the original article resemble generally those we have published from time to time illustrating semi-indirect office lighting, and appear to give a pleasing effect, a good feature being the choice of a design of the cased glass bowls to harmonise with the decoration of the white ceiling from which they are suspended.

We will now give a few additional details regarding the gas and electrical equipment and some data, referring to representative rooms and selected from the table presented by the authors, showing the conditions of illumination.

Gas Lighting.

The semi-indirect bowls employed are of heavy cased glass, the fixture being finished in yellow bronze. The 24″ fixture is approximately 5′ 5″ in overall length, and contains two 5-mantle inverted burners. The corresponding 16″ fixture is 4′ 1″ in overall length and contains one 3-mantle burner. When lighted the bowls give a soft amber hue. The glassware is arranged on a hinged support, making it easy to replace mantles and undertake cleaning operations.

The fittings are all supported with bronze rods, one of which is used to convey the gas to the burners (thus eliminating any unsightly piping and carrying still further the similarity to an electric fitting). Just before the gas reaches the burner a by-pass connection is taken off. On this by-pass connection a small electro-magnet cock controlling the pilot is placed. At the end of the pilot is the filament igniter, a piece of

* Notes on a contribution appearing in the Transactions of The Illuminating Engineering Society (U.S.A.), June 20, 1917.

fine platinum wire which is raised to the ignition temperature by the passage of an electric current (supplemented by the catalytic properties of the wire). The filament is in series with the electro-magnet valve, so that if the latter should be damaged or broken, the valve cannot be opened. Fixtures are controlled separately or in groups of two or three from the same button. Current is supplied from a storage battery and motor-generator set in the basement, automatically controlled so as to keep the pressure between 14 and 15 volts. This set also furnishes current for bells, buzzers, elevator signals, &c., throughout building.

Provision is made for controlling and igniting the fixtures manually in the event of the automatic ignition getting out of order. The direct lighting units are also furnished with electric ignition.

The data in Table I. relating to the illumination in some of the offices are of interest. The illumination was measured in foot-candles in a horizontal plane 30″ above the floor.

TABLE I.—ILLUMINATION DATA FOR GAS LIGHTING.

Room.	Dimensions.		Lighting Equipment.	Illumination.	
	Area.	Ceiling height.		Mean.	Max./Min.
	sq. ft.	Ft. in.		Ft.-c.	
Show Room ..	3,330	15 11	One 24″ semi-indirect fixture per bay, containing two 5-mantle burners. Spacing:—Longl. distance 20′, transverse distance 19′. Bottom of bowl to Floor, 10′ 6″.	4·31	1·8
Book-Keepers' Space	910	12 4½	Ten 16″ semi-indirect units each containing one 3-mantle burner. Spacing:—Longl. distance 10′, transverse distance 9′ 10½″. Bottom of bowl to floor 8′ 8½″.	7·14	1·8
Drawing Office ..	6,345	10 0	Fifty-seven 16″ semi-indirect units, each containing one 3-mantle horizonal burner. Spacing:—Longl. distance, 9′ 3″, transverse distance, 11′. 4 fixtures per bay. Bottom of bowl to floor, 7′ 2″.	7·64	1·4
Board Room. ..	444	10 6	Two 14″ semi-indirect units, each containing one 3-mantle burner. Spacing:—Centre of room, 10′ 10″ apart. Bottom of bowl to floor, 7′ 9″.	3·40	4·2

ELECTRIC LIGHTING.

As regards the electric lighting fixtures it only requires to be said that their design was similar to that of the gas fixtures already described. Dishes varying in diameter from 12″ to 24″ were, however, used.

Some illumination data, similar to those presented above for gas-lighting, are assembled in Table II. The illumina-

tion was again given in foot-candles, measured in a horizontal plane approximately 30″ above the floor. (In certain cases the height of the plane was greater but these are not included among the examples given.

TABLE II.—ILLUMINATION DATA FOR GAS LIGHTING.

Room.	Floor Area.	Size of Bay.	Ceiling Fixtures per Bay.	Diam. of Dish.	Lamps in each Unit.	Illumination.	
						Mean.	Max./Min.
	sq. ft.	Ft. Ft. in.		Inches.		Ft.-c.	
Show Room ..	7,200	23 × 18 7	1	24	6—60w.	11·7	4·69
Drawing Office	7,581	23 × 18 7	4	14	4—60w.	8·0	1·79
Corres. Dept. ..	6,656	23 × 18 7	4	14	4—40w.	4·8	1·95
Executive Office	432	—	1	22	6—40w.	2·3	6·13

LAMP POSTS ADORNED WITH A CITY'S EMBLEM.

THE complaint has often been made that the conventional types of lamp posts installed in great cities lack individuality, show few traces of artistic design, and are rarely designed with a view to harmony with surroundings.

This is a problem which cannot be studied in detail at the present time, but should be taken up after the war. Meantime we notice an attempt at such individual treatment in the city of Alhambra, California, which is referred to in *Popular Mechanics*. The lamp posts in this city, which are of a graceful type carrying three diffusing glass globes, were specially designed for the city. The design, which is copyrighted and cannot be reproduced elsewhere, utilises the insignia of the city, namely, a crescent and a star, which is suggestive of the Alhambra Moorish Palace in Spain. The insignia are worked into the arms supporting the lights and also appear on the sides of the base of the column.

POWER DIRECT FROM SUNLIGHT.

In view of the present shortage of fuel, the fascinating problem of obtaining power direct from sunlight, which has often been the subject of investigation, is again being considered. Reference was made to the subject in a paper recently read by Mr. J. F. Crowley before the Irish Technical Instruction Congress.

It is calculated that the power received from the sun on an acre of the earth's surface on a clear day may amount to as much as 5,000 h.p. The problem is to convert this energy into a useful form. Attempts have been made to use the heating effect of the sun to raise steam.

Meantime we notice in the *Electrician* a summary of a paper read by Mr. T. W. Case before the New York Electrical Society, which refers to a possible direct conversion of light into electric energy, and has distinct theoretical interest. In experiments made in Florida it was found that a current is produced when light impinges on a cell containing two copper plates, one bright and one oxidised, immersed in a solution of sodium chloride. The pressure derived from such a cell, about 0·1 volts, is very small, and the current obtained in these experiments from a single cell only about 1-5th of an ampere. But the effect is interesting, and it is conceivable that by using cells of much larger dimension and a greater number of them, a useful source of power might eventually be developed.

THE COLORATION OF ARC LAMP GLOBES.*

BY M. LUCKIESH.

The purplish tint of arc lamps has been often noted, and it is well known that glasses exposed to sunlight and X-rays may undergo a similar colour-change. The coloration is characteristic of glasses containing manganese, but is not confined to this type. Glasses containing potash, but free from manganese, gradually assume a bluish tinge and those containing sodium a yellowish-green tinge.

From the lighting standpoint, such changes are objectionable because they involve increased absorption. It is of interest to note that the colour is quite unstable and may be caused to disappear by heating with a Bunsen flame. The explanation of such changes is obscure. It is sometimes assumed that the colours of glasses are due to two general states of the metal present. In one state, for example in copper blue-green glass, the metal is assumed to be in solution in the same manner as copper sulphate dissolves in water; in the other state, for example in gold ruby glass, the metal is believed to exist as a colloidal solution. Now manganese is supposed to be present in chemical combination as a salt in a solution of the first kind. It is assumed that radiant energy has the effect of changing the chemical composition of the material, and so producing the purple coloration. The metal, under somewhat similar conditions, has been spoken of as "crystallising out."

Manganese, however, has a certain utility in neutralising the greenish tint normally present in glass containing traces of iron oxide. It is clear, however, that the admixture of manganese leads to increased absorption. For example, if the greenish coloration leads to an absorption of 5 per cent., and the added manganese necessary to neutralise this colour gives an absorption of 6 per cent., then we have, in the total, 11 per cent. absorption. Moreover, there is a gradual increase in absorption as the purple coloration due to the manganese becomes accentuated; in cases examined by the author the transmission has been reduced from an initial 10 per cent. to 25 per cent. due to this cause. In the case of opal glasses the decrease in the coefficient of transmission may be even more rapid owing to the diffusion of light within the material. Few people realise the degree to which this absorption may proceed. The writer has picked up pieces of broken glass from arc lamps which had been in use for some time, and found the transmission to be only one-half that of clear uncoloured glass; on some specimens, in which the purple coloration was pronounced, the transmission varied from 55—85 per cent.

The effect is probably accentuated by illuminants giving much ultra-violet light, but there is ground for thinking that in the case of lamps enclosing tungsten lamps, the effect is mainly caused by sunlight, which may affect ordinary window glasses appreciably. It is well worth consideration whether, for ordinary lighting purposes, glasses free from manganese should not be preferred, even though this would involve a slight greenish coloration.

* Abstract of an article in the *General Electric Review* (U.S.A.).

THE SPECTRAL ANALYSIS OF DYES AND PIGMENTS.

A CONTRIBUTION by M. Luckiesh to the *Journal of the Franklin Institute** contains some useful data on the colour of light reflected or transmitted by various dyes and pigments. In view of the close attention being paid to dye-manufacture in this country the matter deserves careful consideration.

Of the various methods of analysing colour the most accurate and scientific is spectrum analysis. The use of the spectrophotometer enables not only the reflecting power for light of any particular colour, but also the distribution of reflection or transmission for a pigment throughout the entire spectrum to be readily ascertained. If results are expressed in terms of light of definite wavelengths the results can be checked and reproduced by other observers. On the other hand, if one works only with light transmitted through standard glasses or colour solutions, which do not give absolutely pure coloured light, there must always be some doubt about the reproduceability of the results, and their interpretation, although these methods are more convenient for demonstration purposes.

In addition to the study of visible light the transmission of reflection of infra-red and ultra-violet rays is also of interest, and this can be studied by special instruments such as the bolometer, the thermopile and the photo-electric cell. Admittedly there is less precision attainable in this field, especially in regard to ultra-violet light, where differences in wavelength may produce widely different results according to the use to which such rays are put (*i.e.*, whether for therapeutic, photographic, or chemical uses).

The reflection of coloured surfaces can be tested by allowing strong light to impinge on them and then comparing the reflected light with the incident ray with a spectrophotometer. Mr. Luckiesh presents tables of the reflecting power of various pigments (vermilion, burnt sienna, yellow ochre, chrome green, cobalt blue, etc.) studied in this way. Although having a predominant hue, these pigments reflect quite a lot of light in other parts of the spectrum. Moreover, in an accurate study of such materials there are many special circumstances to be taken into account.

For example, the way in which the pigment is applied has a material influence on its colour-value. If the powdered pigment is given a smooth surface by pressure it does not appear as pure in colour as when it is loosely packed, because in the latter case a greater proportion of the incident light is able to penetrate more deeply into the body and become coloured by selective reflections and transmissions. Similarly, the quality of the fabric to which a dye or pigment is applied is not without influence. Two microphotographs of cotton and silk fabrics impregnated with the same dye are reproduced to illustrate this effect. In general the latter permits the radiation to penetrate more deeply and gives a stronger colouration than in the case of the cotton fibres. The refractive index of the crystals of which a pigment is composed will also affect the penetration and therefore the colour, and the size of such crystals will no doubt depend on the method of applying the solution and its concentration. The effect of concentration has not been very fully studied. The transmission is a simple logarithmic function of the depth of a given solution and its concentration, but the relation varies with the wavelength so that, for an impure colour, the calculations would be rather complex. Values of total transmission are, therefore, best determined by direct measurement.

Coloured glasses may be studied in much the same manner as solutions, though the physics of the operation by which glasses are coloured by metallic ingredients are by no means clear. In some glasses the colour is believed to be due to the suspension of minute particles

* The Physical Basis of Colour Technology, by M. Luckiesh, *Journ. Franklin Institute*, July, 1917.

of metal in a colloidal state. By illuminating specimens obliquely with strong light, and viewing them under a microscope, Siedentopf and Szigmondy have detected the presence of such particles. In other cases the metal appears to enter into a state of true solution, in the same manner as a salt in a liquid solvent.

A determination of transmission or reflection coefficients of a coloured surface or medium respectively must be made with respect to the incident light. Naturally the nature of the emerging light will depend on the character of the light impinging on the surface or solution. A coloured fabric, as is well known, varies considerably in appearance according as it is viewed by daylight, or by light from the arc-lamp, the incandescent mantle, the electric glow-lamp, etc. Even the variations in daylight itself at different periods in the day and year cause such differences. Mr. Luckiesh presents diagrams showing the reflection coefficient throughout the spectrum of pigments by noon sunlight, blue skylight, and tungsten (vacuum) filament lamps. A truly white surface should return a spectrum identical with that of the impinging light, but a coloured medium, exercising selective reflection, will not do so. This quality has been suggested as a criterion of a "white" surface, and there are many materials which, for practical purposes, approach very closely to this condition (such as pressed magnesia, zinc white, etc.). Yet, if the light is made to undergo successive reflections, a difference in tint may be revealed even in the cases of so-called white surfaces. If, for example, a box or sphere is coated internally with a supposedly neutral pigment light entering the enclosure undergoes innumerable successive reflections and transmissions, and the emergent rays may therefore be appreciably altered in spectral composition.

It is also worthy of note that many approximately white surfaces differ widely in their power of reflecting ultra-violet light. Zinc white, for example, absorbs ultra-violet energy very freely. Similarly it has been shown that cobalt oxide is a much better reflector of infra-red energy than zinc white, although for visible rays its reflecting power is vastly less. Again, lead oxide is a much more efficient reflector of long-wave energy than zinc oxide, magnesium carbonate, and other white pigments.

It has been remarked that coloured solutions in general transmit more or less impure light, although in some cases it is possible to get a very narrow band of transmission. It is noteworthy that there is no known dye which transmits only a narrow region near spectral yellow. In cases in which several colours are transmitted with different ease the colour of a solution will depend to some extent on its depth and concentration. In some cases, *e.g.*, fluorescein and uranine, the effect is complicated by marked fluorescence.

OPPORTUNITIES FOR GAS IN FOREIGN LANDS.

In the *Gas Age* Mr. F. J. Koch points out the opportunities for gas in central Europe after the War. At present in these lands houses are lighted almost exclusively by candles, tapers and oil lamps. In the Danube and Balkans the candle is paramount and expensive. Most of the people work on the farms and, retiring very early in the evening require little or no artificial light; but if illumination were more abundant they would doubtless make more use of the evening.

Even hotels rely chiefly on candles. It is customary for a new candle to be placed in every room when a customer arrives; if he should merely light this candle for a minute and then extinguish it he would be charged for the entire candle in the bill.

Oil lamps are also widely used. In the Greek churches the old dim religious light from a single large oil lamp, supplemented by candles is usual, and the streets of the capital of Montenegro are still lighted by oil lamps.

REVIEWS OF BOOKS.

The Range of Electric Searchlight Projectors, by Jean Rey, translated by J H. Johnson, M.I.E.E., Assoc. A.I.E.E. (Constable and Co., Ltd., London. 1917, 12*s.* 6*d. net ; pp.* 152, 32 *illustrations,* 8 *plates.*)

THE present conflict has greatly stimulated interest in searchlights. Those who have studied the subject are aware of the lack of up-to-date information on the latest developments, particularly on the conditions governing their effective use. The above work deals with an aspect of the matter on which very little has been published. The "candle-power" of a searchlight is to many people a vague term, while the factors determining range are still only imperfectly understood. Prof. Blondel has done much valuable pioneering work in this direction,* and both he and M. Rey have taken up the study of range energetically in France. Mr. Johnson's translation of the latter's work is therefore timely.

The book proceeds in logical sequence, the distribution of light from a projector and the determination of luminous flux being first explained, and the illumination theoretically obtainable from a reflector of specified dimensions calculated. The chapter on the efficiency of searchlights, in which the losses of light due to obstruction, reflection from the mirror, obscuration of the atmosphere, &c., are analysed, breaks new ground, and the same applies to Part II., in which the range of searchlights is fully discussed. Here the reader gains an insight into the many disturbing factors on which effective range depends, and M. Rey is at pains to illustrate each point by worked examples referring to observation of distant fortresses, battleships, gasses of troops, &c., which give a clear conception how these theoretical data may be effectively utilised in war. The book contains a number of valuable plates containing data relating to the range with atmospheric absorption and other factors.

We think that the book should prove extremely useful to artillery officers and others interested in the technical applications of searchlights, while to the illuminating engineer it presents an instructive example of the utility of the conception of flux of light. Mr. Johnson may be congratulated on having brought the work within the reach of English readers. We notice a few slips in translation, most of which, however, are corrected in the *Errata* table, and in view of the complexity of the subject there are some passages which might perhaps be reworded with advantage in the next edition. The printing and paper are good and the diagrams clear, and there is an adequate index.

* *Illum. Eng.*, Feb. and April, 1915.

Journal of the Society of Glass Technology, Vol. 1, *No.* 1, *May,* 1917. (*Published by the Society of Glass Technology. Sec. : Dr. E. W. E. S. Turner, The University, Sheffield.*)

DURING recent years we have had to record many interesting developments in the scientific world, and to all of us the need for closer study of certain fields of knowledge has been very clearly indi-

cated. Glass technology offers a good illustration of such a subject. The war has revealed the vital necessity for a more scientific study of the processes of glass manufacture, and the applications of glass in various scientific and optical instruments. In illuminating engineering the matter was early brought to our notice in connection with the difficulties in the manufacture of illuminating glassware, but there is scarcely any field of knowledge into which optics and glass technology does not enter to some extent.

The formation of a Society of Glass Technology, with its headquarters at Sheffield University, where a special department has been formed to study this subject experimentally, was therefore a welcome step forward. From the first volume issued by the Society we note that it is receiving the co-operation of a number of leading glass manufacturers, as well as professors, Government officials and others interested in the utilisation of optical glass. We observe further that "all persons interested in glass, whether from the point of view of the manufacturer, the distributor, the scientist, the user or collector, are eligible for membership. This wise distribution of interests, which resembles that adopted in the constitution of the Illuminating Engineering Society, should be conducive to most useful work, and the first number of the *Transactions* affords evidence that valuable investigations are already being undertaken.

The original papers contributed to the Society deal with such subjects as British Glass Sands, the Annealing of Glass, and the Influence of Small Quantities of Chlorides and Sulphates in Producing Opalescence. A particularly interesting paper is that by Mr. T. Teisen on the Development of Glass Furnaces on the Continent.

Not the least valuable feature in the Transactions, however, is the section devoted to abstracts and reviews of papers and articles dealing with glass technology, which are classified under five headings. Hitherto, we believe, there has been no similar attempt to collect such literature in this country and the regular presentation of such data should be extremely valuable.

We trust that the formation of this Society will mark the beginning of a new era in glass technology in this country, and we hope that it will meet with well-deserved success. Much of its work is of direct interest to the illuminating engineer, and we feel sure that valuable results would follow from its co-operation with the Illuminating Engineering Society in studying such matters as the qualities of illuminating glassware, both from a manufacturing standpoint and from the practical aspect as distributors of light.

The International Industrial Institute: Safety Engineering Lessons.

WE have received from the International Industrial Institute (Home Office, Little Buildings, Boston, U.S.A.) particulars of courses of Safety Engineering, covering the whole field of safety and industrial hygiene and leading to the degree of "Safety Engineer." The authors of the course are the Hon. Dudley M. Holman, who was a member of the Massachusetts Industrial Accident Board from its inception, and Dr. W. H. Tolman, who was the founder and first director of the American Museum of Safety.

We understand that these courses are being encouraged by many experts associated with industrial concerns and the booklet received contains warm expressions of appreciation from many leaders of industry, officials of insurance companies, and others concerned with safety and the prevention of accidents.

That there is need for such a movement is shown by the figures quoted for the State of Massachusetts. In this State alone, 150,000 accidents were reported to the Industrial Accident Board in 1916, and 2,838,448 dollars were paid out in 1915 for compensation and medical treatment. In the whole of the United States, 32,000 accidental deaths in industry are reported annually, over 250,000 men and women are permanently incapacitated by accidents and industrial diseases, and over 3,000,000 are injured by accidents each year. It is estimated that mechanical safeguards will prevent only 10—20 per cent. of accidents. The rest of the problem is educational. Dr. F. W. Loughran, M.D., Medical Adviser to the New York State Insurance Fund, estimates that on the average each industrial worker in the United States loses nine days yearly through sickness; as there are about thirty million workers in the United States, the resulting economic loss, both to workers and manufacturers, can be readily estimated.

We wish the movement inaugurated by Mr. Holman and Dr. Tolman every success, and trust that the variety of accidents in which this journal is primarily interested, *i.e.*, those due to inadequate lighting, will receive special attention.

CORRESPONDENCE.

FLUORESCENCE AND PHOSPHORESCENCE.

SIR,

Dr. Sheppard, in his communication appearing in THE ILLUMINATING ENGINEER for June, contends that phosphorescence, unlike fluorescence, "is associated with the presence of stray or unsaturated affinities due to free, usually metallic, nuclei, of several valency stages, in colloidal or solid solution in the material." And he adds that "this conclusion is not new, but was established by the work of Lecoq de Boisbaudran."

It is true that Lecoq de Boisbaudran sought to establish that phosphorescence (including both phosphorescence and fluorescence) depends upon a pre-existent solid solution. But when Dr. Sheppard continues: "I have obtained evidence in the same sense in reference to calcium tungstate," he is adducing evidence against this savant's contention, for, according to Boisbaudran's school, the whole of luminescence, and not only the phosphorescence of calcium tungstate, is due to undiscovered impurity.*

It is therefore clear that Dr. Sheppard and the authority referred to are using the word "Phosphorescence" in different senses. In the discussion before the Illuminating Engineering Society to which Dr. Sheppard refers, I pointed out that, owing to the relegation of the word "phosphorescence" by Stokes to a side issue, it was no longer permissible to speak of the phosphorescence of phosphorus. Now Dr. Sheppard goes even further, and introduces a definition of fluorescence which will not allow us to speak of the fluorescence of fluorspar (an impure substance)! Yet Stokes himself derived fluorescence from fluorspar, so that his nomenclature is in turn being assailed.

As an illustration of my remark that there is no essential difference between fluorescence and phosphorescence (using these words in Stokes's sense) I demonstrated, at the meeting referred to, the effect of heat upon a typical phosphorescent substance, zinc sulphide, which is both phosphorescent and fluorescent at ordinary temperatures. At about 100° C. this substance was brilliantly fluorescent but no longer phosphorescent. I next showed two specimens of manganiferous zinc sulphide both brilliantly fluorescent at ordinary temperatures; one of these specimens exhibited a brilliant after-glow, the other nothing. Dr. Sheppard's new definition of fluorescence would ignore these phenomena, and is also inconsistent. For example, Dewar* has stated:—

"When ammonium platinocyanide is cooled with liquid air and maintained at this temperature by being immersed in the liquid while still stimulated by exposure to a beam of the electric arc, it continues to glow in the dark with a feeble emission as long as the temperature is kept about −180° C. . . . On pouring off, however, the liquid from the crystals so that the temperature may rise, the interior of the test-tube glows like a lamp."

We see, therefore, that pure ammonium platinocyanide, usually a perfect example of fluorescence and an example conforming with Dr. Sheppard's definition, may, by suitable experimental conditions, be made to exhibit phosphorescence; thus assuredly florescence and phosphorescence represent "a distinction without a difference."

Moreover, Lecoq de Boisbaudran was incorrect in thinking that these nuclei must be pre-existent. They must be existent at the moment of luminescence, even in pure nonvalent neon, and in pure calcium tungstate. Where these nuclei come from when not originally present would present a fascinating study to the photochemist. But the permanent or evanescent nature of the nuclei has little to do with the question, whether or no there is an appreciable "time-lag." I cannot here attempt a full explanation of the origin of the "lag," but it depends on quite another matter. It is briefly an expression of the rate at which (under given conditions of temperature, method of experiment, and mode of production of the substance) association follows dissociation. It is the association that gives rise to the form of energy ultimately transformed by the nuclei into light, but all these associations, &c., are merely important side issues. There is only one type of luminescence—the conversion of an acceptable form of energy, by an acceptable form of nuclei, into light.

In stating that "the luminous response depends largely upon the crystalline solid structure," Dr. Sheppard overlooks the fact that many gases and liquids are brilliantly luminescent. The variety of willemite made by me is a vitreous substance with a conchoidal fracture. Nevertheless it is brilliantly luminescent. I have never seen a crystalline luminescent alkaline-earth sulphide, and I believe that

* Bruninghaus Ann. Chim. Phys., 20 and 21, 1910.

* Proc. Chem. Soc., No. 142, 1894.

crystallisation has even less to do with luminescence than with transparency. Luminous response depends very little upon crystalline solid structure; it may come in as an accidental accompaniment of thermal treatment, but is not one of the main issues. Moreover, crystallisation is itself something even more mysterious than luminescence, and to explain an unknown by reference to an even greater unknown is not a move in the right direction.

As regards the behaviour of calcium tungstate, I may add that if Dr. Sheppard had used the ultra-violet energy from an iron spark instead of **X**-rays he would have found that even merely dried precipitated calcium tungstate luminesces quite well.

By using calcium molybdate instead of calcium tungstate he will detect the luminescence even more readily. Zinc and cadmium tungstate also luminesce when merely dried, and in all these cases the maximum response to the iron spark is induced at a much lower temperature than the maximum response to **X**-rays.

I am in full agreement with Dr. Sheppard that *pure* calcium tungstate is luminescent, but only by a great number of converging experiments can this be proved, and in order to satisfy the disciples of Boisbaudran's school it must be proved absolutely conclusively.

I also agree entirely with Dr. Sheppard that the after-glow usually exhibited by calcium tungstate is due to an impurity, but the impurity is a "metallic nucleus" that does not contain tungsten. The reducing agency merely liberates the "metallic nucleus" from an innocuous metallo-tungstate, and can be just as well brought about by oxidising or neutral agencies of a selected character, provided of course that the metallo-tungstate is present in the precipitate. So far as I know calcium tungstate cannot be obtained pure by a wet method, though the ever-present impurity can be volatilised off by a furnace method.

Yours, &c.,

A. L. Landau,

Luminescence Laboratories,
Cold Chemical Co., London, N,

Sir,

Dr. Sheppard and Mr. Landau have discussed the desirability or otherwise of drawing a distinction between fluorescence and phosphorescence, chiefly from the chemical standpoint.

But from the physical standpoint there is also a means of deciding whether this is indeed "a distinction without a difference." Whatever the chemical basis of these phenomena I imagine it will always be necessary to use some term (such as "after-glow") to denote an effect which is very persistent after excitation. But if it could be shown that fluorescence always involves phosphorescence, *i.e.*, that there is always some after-glow, though the period during which the glow persists may be exceedingly small, this would go far towards showing that the two effects are one.

Physicist.

THE GOVERNMENT AND PUBLICITY.

Sir,

I believe that very shortly the Government will be making a fresh appeal to the public for more money to carry on the War. I would suggest to those responsible for the Government publicity that the people who have the money to invest are the employers and employees. The money is being largely made in the Midlands, Yorkshire, and North of England manufacturing districts, and the best and surest way to get them interestsd is through their Trade Journal, produced for the purpose of promoting their interests and extending their trade at home and abroad.

The *Engineer, Engineering, Textile Recorder, Textile Mercury, Dyer and Calico Printer, Colliery Guardian, Ironmonger, Chemist and Druggist, Drapers' Record, Cabinet Maker, British Trade Journal, Oil and Color Trades Journal*, &c., to quote a few (according to Mitchell's Newspaper Press Directory there are over 500 Trade Papers published in this country), represent trades in which is invested many millions of capital.

The Trade and Technical Press represent the motive power of English industries, and is therefore one of the greatest assets the country possess, and up to the present time has not been recognised by the Government, except to a small extent, when the Coal Control Committee made an announcement in a few trade papers.

The readers of these papers have the money. Next time the Government is asking for money, why not make their appeal to this great industrial class, the men who have worked hard to make their money and who want a safe investment like the 5 per cent. Exchequer Bonds or the War Loan, through the Trade Press, in addition to the Daily Press?

Yours &c.,

Walter Judd.

TOPICAL AND INDUSTRIAL SECTION.

[At the request of many of our readers we have extended the space devoted to this Section, and are open to receive for publication particulars of interesting installations, new developments in lamps, fixtures, and all kinds of apparatus connected with illumination.

The contents of these pages, in which is included information supplied by the makers, will, it is hoped, serve as a guide to recent commercial developments, and we welcome the receipt of all *bona-fide* information relating thereto.]

BRITISH WESTINGHOUSE MOTORS AND GENERATORS IN INDUSTRIAL SERVICE.

A useful Instruction Book (No. 5010/1) issued by the British Westinghouse Electric and Manufacturing Co., Ltd., deals with the installation, operation, care and repair of motors in industrial service. The first section deals generally with installation and contains suggestions regarding unpacking, drying out, foundations, erection, etc. Of special utility are the notes on the mounting of vertical motors, and the arrangement of motors on walls and ceilings, and the hints on the lubrication and care of bearings.

Electrical connections, and details of operation such as starting and stopping, and repairs are next discussed. D.C. and alternating motors are separately treated.

FIG. 1.—Protected Type Vertical D.C. Motor.

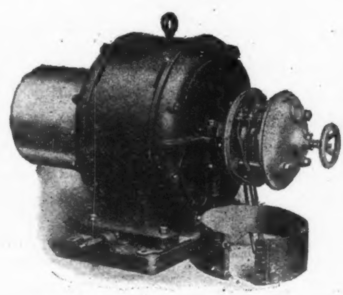

FIG. 2.—Slip-ring Motor with combined brush-lifting and short-circuiting gear.

In the final section of the booklet there are a series of illustrations of typical alternating and D.C. motors, two of which are reproduced in Figs. 1 and 2. The protected type vertical D.C. motor strikes one as a particularly compact and convenient form.

The instructions throughout are clear and definite. We are glad to note this instance of the growing recognition among leading electrical manufacturers that explanations and instructions should supplement catalogue literature. In this way manufacturers can take a useful part in the technical education of the country.

HAWKINS' ELECTRICAL GUIDES.

We are asked to state that the above guides, to which reference was made in our May issue (p. 144), can be obtained from Mr. Geoffrey Parker (29, The Avenue, West Ealing, London, W.13).

THE FEDERATION OF BRITISH INDUSTRIES.

We observe that the Executive Council of the Federation of British Industries has issued a memorandum commenting on the recent Whitley Report on Relations between Employers and Employed. It will be recalled that the latter report advocates the setting up of Joint Standing Industrial Councils, District Councils, and Works Committees representative of employers and employed in each particular industry.

The memorandum issued by the Federation of British Industries recommends that the basis of such a scheme must be trade councils of masters and men, which should have sole power of dealing with agreements and matters of common interest. The main function of district councils should be to act as Courts of Arbitration while the works committees should be voluntary, and should be composed exclusively of employees, preferably elected by ballot. Their duties should be confined to reporting or receiving from the management complaints of any breaches of agreement that occur.

In short, the general policy of these councils should be centralisation of policy and decentralisation of administration.

ILLUMINATING GLASSWARE.

A list (No. 10300-A) issued by the British Thomson-Houston Co., Ltd., contains particulars of ornamental glassware of the Veluria, Alabas, Calla and other types in the form of bowls, spheres and reflectors. There are also illustrations of pleasing designs of dishes of Florentine and Tuscan alabaster. The illustrations of these various units are well executed and the whole get-up of the catalogue is attractive.

In view of the necessity of softening the light from modern high candle-power units by diffusing fittings, it is satisfactory to see that they are receiving such detailed attention and are available in such variety.

PERSONAL.

We are informed that Mr. E. Stroud, who is associated with Holophane, Ltd., and is a member of the Illuminating Engineering Society, has received a commission as Lieutenant in the Royal Naval Volunteer Reserve. Readers will join us in wishing him success in his new work.

The *R. Istituto Tecnico E. Nautico* (Genoa) has issued a bulletin containing the address of Sig. G. Reggio descriptive of the work of the late Professor S. A. Rumi, of Genoa, who was a valued member of the Illuminating Engineering Society. There is also a bibliography of Prof. Rumi's most important contributions to electrical technology. The death of Professor Rumi has already been recorded in these columns, and has been received everywhere with sincere regret.

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THE HALIFAX CORPORATION SUB-STATION.

In order to afford a supply of continuous current to the outlying areas of Hebden Bridge and Hipperholme, the Halifax Corporation have recently laid down two converting stations in these districts. The contract for electrical equipment was entrusted to the General Electric Co., Ltd. The converting unit chosen was the 250 k.w. "Witton" rotary converter, together with an oil insulated air-cooled transformer taking in three-phase power at 6,000 volts and generating at 550 volts for traction and 220—0—220 volts for lighting. The incoming feeders are controlled in each substation by "Witton" mistake-proof switchboards. The low-tension boards include both traction and lighting panels, and simple change-over switches are included for applying machines either to lighting or traction. Indebtedness is expressed to Mr. W. M. Rogerson, M.I.E.E., the Borough Electrical Engineer of Halifax, for permission to take photographs and publish a description of the plant.

THE WILD-BARFIELD SYSTEM OF STEEL-HARDENING.

The above process, as exhibited at the Westminster Electrical Testing Laboratory, is being largely applied to the hardening of steel gauges. It had been found previously that in the process of hardening irregularities occur, the diameter and pitch of the screw being affected. Such distortions can only be corrected afterwards with considerable difficulty.

By the Wild-Barfield process, it is claimed, these changes of shapes do not take place. The gauge to be hardened is immersed in a special salt solution heated by the passage of a current through a spiral coil of wire surrounding the cylinder containing the liquid. The correct temperature is checked by observing the "decalescence point" as revealed by sudden loss of magnetism on the part of the gauge. This point is indicated by the deflection of a galvanometer connected to a coil wound round the exterior of the furnace.

The gauge is magnetised by the current flowing through the helix surrounding it, and at the decalescence point the rapid collapse of the lines of force induces a current in the external coil connected to the galvanometer. This current rises to a maximum and then dies away as the non-magnetic stage is reached. The spot of light from the galvanometer therefore deflects and then returns again to zero.

The gauge is afterwards immersed in a special quenching solution of low vapourising point. The ingenious method of controlling the temperature, together with the effect of the special quenching solution in eliminating local evaporation and consequent changes of temperature, is stated to remove the danger of distortion which has previously been a difficulty in gauge-hardening.

CHILIAN SECTION OF THE PANAMA-PACIFIC EXHIBITION.

We have received from Mr. B. B. Sanchez (Santiago de Chile), the Secretary of the Chilian Section of the Panama-Pacific Exhibition, a booklet published by the Chilian Government describing the natural resources of the country, especially in regard to minerals of various kinds.

The information presented will no doubt be of interest to those in this country desiring to enter into business relations in Chile, to whom Mr. Sanchez offers his services.

MERCURY VAPOUR CONVERTERS.

List No. 75b, issued by the Westinghouse Cooper-Hewitt Co., Ltd., describes the construction and use of mercury rectifiers for conversion from alternating to direct current. A special feature is a series of rectifiers for charging telephone batteries.